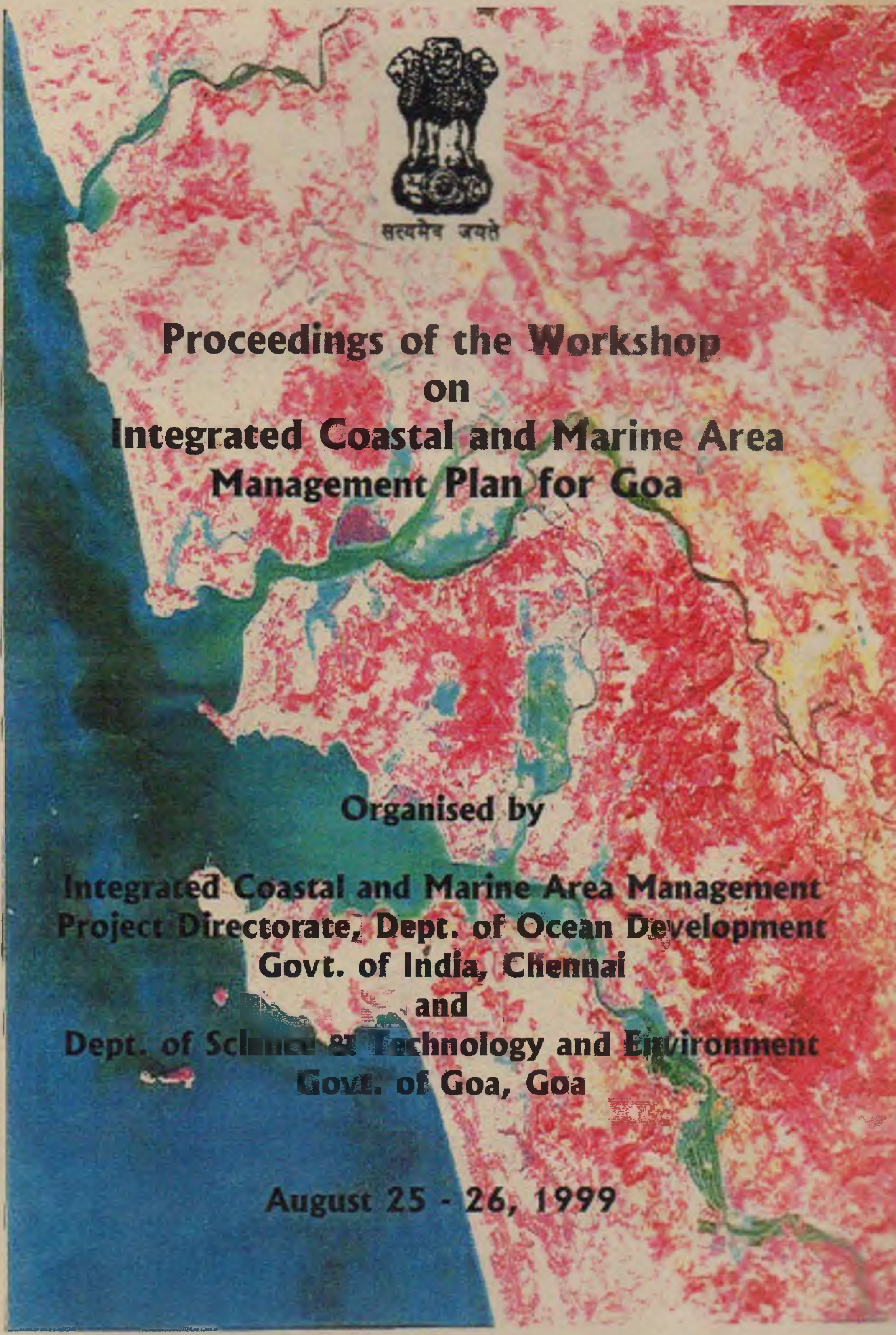


सत्यमेव जयते

Proceedings of the Workshop on Integrated Coastal and Marine Area Management Plan for Goa

Organised by

Integrated Coastal and Marine Area Management Project Directorate, Dept. of Ocean Development
Govt. of India, Chennai
and
Dept. of Science & Technology and Environment
Govt. of Goa, Goa

August 25 - 26, 1999

MINING ACTIVITY IN THE CATCHMENT AREA AND ITS IMPACT ON MANDOVI - ZUARI ESTUARIES OF GOA

G.N.Nayak
Department of Marine Sciences and Biotechnology
Goa University
Goa

Abstract: *In recent years, human activities like deforestation and associated mining, agriculture etc have enhanced release of material to the river system many fold. It is also argued on the other hand that, due to damming or diversion of river, material release has decreased. Either enhance or decrease is known to cause impact upon river / estuary especially on its processes. The studies carried out on the Mandovi - Zuari estuarine ecosystem of Goa, revealed that human interference in the catchment area of these rivers, which lead release of additional material, has affected this estuarine environment to considerable extent.*

Coastal Zone: The coastal zone is characterized by variety of land forms like beaches, estuaries, lagoons, islands etc., in and around them, number of specific biological communities develop including inter-tidal, marsh, mangrove, sea grass, coral reefs etc. Each of these communities live in well defined coastal environments.

Release of additional load to the coastal environment or reducing the load would cause major impact upon coastal zone in the form of change in coastal processes, leading to coastal degradation problems such as destruction of living resources and also erosion. These have become issues of major concern today. Earlier studies along coastal areas of the country reported several problems that threaten the proper management and sustainable development of the coastal zone.

In recent years, human activities like deforestation and associated mining and agricultural activities have enhanced the release of material many folds. In contrary some researchers state that river discharge has decreased due to damming or diversion.

Estuary is one of the important ecosystems (Fig.1) of coastal zone. Some of the important works carried out on estuaries in India, during the last decade and a half, basically deal with biological, bio-geochemical, geochemical, physico-chemical and geological aspects. Important contributions are those of Borole et al., (1982); Balakrishnan et al, (1984); Nair et al., (1990); Nayak (1993), Nayak and Bukhari, (1993), Bukhari (1994). An important contribution to the estuarine research in India, is a volume edited by Nair (1989), which comprises of contributions related to suspended sediment distribution, sediment texture, pollution by metals, physico-chemical aspects and also estuarine management.

GOA AS A STUDY AREA

Geomorphology of Goa: Geographically the state is located along the mid West Coast of India. It covers an area of about 3702 sq. km., and from North to South, the coastline stretches to a length of about 105 km., and from East to West it is 65 km., wide. It is bound between the co-ordinates N 14° 54' to N 15° 48' and E 73° 40' to E 74° 20'. Flanked between the continuous range of rugged hills constituting the Western Ghats on the east and the vast expanse of the Arabian sea on the west, the region consists of a chain of high and prominent hills, characterised by deep gorges, steep valleys and ravines. Broadly, there are three main physical divisions (Fig.2)

(a) Hill ranges of the Sahyadri's in the east cover an area of about 600 sq. km. with an average elevation of 800 m.
(b) middle level plateaus in the center sub-ghats and
(c) The low-lying river basins and the coastal plains.

The Western Ghats comprise of denudational hills along eastern margin of Goa. They are characterised by deeply dissected steep escarpment zone towards the west. The sub-ghats form the dissected low denudational hills rising above etch plains to a maximum elevation of 461 m from mean sea level and are characterised by laterite capping. The hills/plateau are typical landforms that are characteristic in that the tops are fairly level, but in places are deeply notched by gullies and the plateau rims are noticeably sharp. The coastal track principally consists of linear stretches of beaches between rocky promontories.

Bordering the state, towards the north is the Sidhudurg district of Maharashtra state and to the east is the Belgaum district and the south is the Uttara Kannada district of Karnataka State. Goa is divided into two districts namely the North Goa and the South Goa. There are 11 Taluks spread over these districts. They are Tiswadi, Bardez, Pernem, Bicholim, Satari, Ponda, Sanguem, Canacona, Quepem, Salcete and Marmugoa. Goa being part of the West Coast region of India, many physical features are common to the neighbouring regions of Maharashtra and Karnataka States. Goa is endowed with natural scenic beauty enriched with lovely beaches, lakes, waterfalls, and green forests making it a tourist paradise.

Climate: The climate of Goa state is generally warm and humid. The annual climatic pattern in Goa has been traditionally divided into three seasons i.e. the Monsoon season from June to September, the winter season from December to February, the summer season from March to May. The maximum temperature is recorded twice during the year namely in October and May. Climate in Goa is dependent on monsoon season. The state receives an average rainfall of 3000-3500 mm. Over 90% of which is received in 2 to 3 months.

Geology: Goa is dominantly covered by the rocks of the Goa group (Fig.3), belonging to the Dharwar super group of Archaean proterozoic age except for a narrow strip along the northern corner occupied by the Daccan traps of upper cretaceous to lower eocene age. The Dharwarian rocks which extend in a general NW-SE trend are represented by metamorphosed basic and acid volcanic rocks and sediments at the base overlaid by greywacke suite of rocks, which in turn is followed by pyroclasts and tuffs with the associated chaemogenic precipitates of lime, manganese and iron and this again overlain by greywacke suite of rocks.

Minerals and Mining: The state of Goa is rich in minerals such as iron ore, manganese ore, bauxite, silica sand, high magnesia limestone and clay. At present, iron and manganese mining are the major extractive industries of Goa. Iron ore mining is predominant in terms of production and export. Present annual production of iron ore is around 13.5 to 15 million tonnes. Mining industry here is mainly export oriented and it contributes to about 10% of the state's economy. Estimated iron ore reserves are 1400 million tonnes and with the present rate of production, mining can continue at least till 2030(Nayak, 1994).

The first reference to the mineral contents in soils of Goa dates back to the 16^{th} century. A Dutch traveler by name Mr. John H. V. Linschoten had written that in Goa there are many stones containing iron (Gune, 1979). However, little attention was paid to their study or exploitation till almost the beginning of this century. In the year 1905, a few French and German companies had carried out prospecting for iron and manganese in Goa. The first concerted attempt was made by Oertal (1954-1957) a German geologist, during the Portuguese rule, produced a geological map. After the first world war there was a sudden rush for mining rights and people acquired "Mining Concessions" from the Portuguese authorities (Salgaonkar, 1991). In this process almost the entire mining belt (Fig.4) of Goa was leased out to private mine owners. However, no large-scale mining industries existed during Portuguese rule, though actual mining started from 1949. For about first ten years, the mining was manual and the production was mainly manganese and ferro-manganese. In 1959, the production of iron ore was picked up and within period of three years it transformed to mechanized mining. Today mining is a highly sophisticated, capital-intensive industry.

Total area covered by the mining leases in 1973 was 65400 hectares and in 1993 it was 31510 hectares. There were 581 mining concessions/leases, out of which 211 were reported working during 1980. There are in total 382 mines out of which only 112 are working at present. Maximum area under mining lease is in Sangeum Taluka followed by Bicholim, Satari, Quepem and Ponda. However, major mining activities are confined to Bicholim Taluka followed by Ponda and Sangeum.

Mining here in Goa is basically open cast type with typical bench and slope configuration. Open cast mining involves the systematic removal of overburden by performing bench and slope method along hilltops and slopes as iron ore deposit lie under a thick mantle of iaterite. The benches and slopes are made according to the strike of the ore body. Mining operation involves drilling, blasting, ripping, dozing, loading, waste disposal, sizing and washing of ores in beneficiation plants (Reddy, 1985). In case of iron ore, as massive quantity of material is handled, mining operations are generally mechanized. Most of the minefields at present are working below the water table. The overburden is stripped away to recover ore by using bulldozers, scrapers etc. It consists of laterite, lateritic clay, manganiferrous clay and phyllites. Thickness of the overburden varies between 10m and 30m. Ore occurs in the form of powdery ore horizon and also as lumpy ore horizon.

With depletion of high grade ore reserves and strict quality ore standards demanded by steel mills, processing has also undergone changes and all major producers of iron ore have erected washing or beneficiation plants. The aim is to minimise alumina, silica and phosphorous. Lime, aluminium sulphate polyaluminium chloride and different forms of polyacryl amides (Magnafloc LT 25 and Magnafloc 1101) are being used in beneficiation plants. There are over 30 main beneficiation plants. Four Pelletisation plants have also been installed for converting the powdery ore into pellets.

Certain natural factors have been directly responsible for the growth and the flourishing progress of the mining industry in this state.

a) Presence of a very good natural harbour at Marmugao, which is situated on the southern bank of Zuari estuary and is one of the best natural harbours along the West Coast of India, with a handling capacity of more than 10 million tonnes of iron ore export annually.

b) Number of navigable perennial rivers and streams. The Mandovi and Zuari rivers, their tributaries and the Kumbarjua canal are the key factors in maintaining the economic viability of Goa's mines. The river system is navigable throughout the year with the Kumbarjua canal providing sheltered passage from the Mandovi to the Zuari river during monsoon. Barging costs for transport of the ore to Marmugao harbour are lower than the cost of road or rail Transport.

c) Distance between mines and loading platforms - The distance from mines to jetties vary between 10 to 30 km. Trucks of 8-10 tonne capacity, from mines to the loading platforms are transporting ore. There are over 84 loading jetties.

Mandovi-Zuari estuaries: The state of Goa has one of the best waterways network. There are seven main rivers (Fig.5) of which Mandovi and Zuari are the most important. Their basin area covers 69% of the total geographical area of the State.

Mandovi is the largest among all the rivers. It originates from parwa ghat a section of the Western Ghats in Karnataka State and traverses about 75 kms before it joins the Arabian Sea. It can be classified as coastal plain or drowned river valley estuary and it shows submerged extension of a former river valley with opening towards the sea. Mandovi covers a basin area of 1530 sq. kms. and a catchment area of 1150 sq. kms. It is joined by vast tributary system along its coasts and a narrow bend and shallow depths mark it. Several islands within the river are characteristics of Mandovi. At the mouth between Aguada and cabo headlands, it measures 3.2 kms, but it narrows down to less than one kilometer within 4 kms, upstream forming a bay structure. Further upstream it narrows to near 0.25 Kms water depth is about 7.5 m. at the mouth and 2.5 m. at upstreams, with an average depth of 3.5 m. It is funnel in shape. Near the mouth, within the bay, it is characterised by the presence of two shoaling zones namely the Aguada bar and the Reis Magos Bar. The river is navigable upto 42 kms upstream, which marks the estuarine limits of Mandovi. River Madei and River Khandepar are two main perennial feeding rivers. Other tributaries are river Mapusa, river Volvota, river Roger and river Nagoa.

It is important to mention here that river Mandovi and its tributaries for most part of their lengths pass through regions of extensive mining activity of basically iron and manganese ore. There are 27 major mines within the Mandovi basin and the river provides cheap and effective means of transport of iron ore from hinter land to Marmugao harbour and banks of its tributaries lined with mined material, loading platform, beneficiation plants, ore stores, massive dumps of rejects, particularly in the upper estuarine regions.

Zuari River is about 70 kms in length with a basin area of 973 sq. kms. of which the catchment area is 550 sq. kms. Comparatively smaller tributary system exists relative to Mandovi. In the mouth region Zuari is 5.5 kms wide within which Marmugao harbour is located. Unlike Mandovi the source of water of Zuari river lies entirely within Goa. The river receives major supply of water and sediments from its tributary known as Kushavati. The drainage area of Kushavati consists of alluvial land, subdued plateau and prominent hills especially in the upstream. In the down stream the tributary develops alluvial flats and marshes on either side. But are more extensive on the left hand.

Kumbarjua canal is unique in that it joins the two rivers within their estuarine reaches. It is 17 kms in length and aligned roughly in North-South direction. It joins Mandovi and Zuari at a distance of 14 kms and 11 kms respectively from their mouths. The fresh water flows from Mandovi to Zuari through Kumbharjua canal during the monsoon period. Tidal influx flows in the opposite direction in the Kumbarjua canal.

The tropical wet evergreen forests occur in deeper valleys of the Western Ghats of Mandovi-Zuari river basin. The tropical moist deciduous forests also occupy large area in the hinterlands. Many evergreen types occupy the lower parts. The hard, dry and shallow soil of lateritic plateaus that are helpful in regeneration of plants like cashew nuts are the lower areas.

The mangrove forests are extensive in estuaries of Mandovi and Zuari rivers. Particularly in the silted up fringes of the Kumbarjua canal. The total estimated area covered by mangroves in the estuarine region is around 1500 hectares. Mangrove vegetation consists of 15 species under 10 Genera and 7 families. The dominant species are *R. mucronata, S. alba, S. caseolaris, A. officinalis, A. alba, E. agallocta, K. Candel, A. ilicifolius, D. heterophyila* and *R. apiculata.*

On the basis of salinity gradient and substratum, the following pattern of succession can be observed in the mangrove vegetation along the estuaries of Goa.

(a) Because of high salinity (30-35 ^{ppt}) towards the mouth of the estuaries, strong wave actions and rocky/sandy substratum, the situation is un-favorable for establishment of seedlings and therefore, no mangroves.

(b) Moderate salinity (18-30^{ppt}), less wave action and clayey substratum, condition of middle estuary is favorable for flourishing mangroves. *S. alba, R. mucronata, A. officinalis, A. ilicifolius* are the most common mangroves ever seen in these estuaries. The Mandovi estuary, in its middle reaches, branches off into river Mapusa on the northern side and river Mandovi on the southern side, forming an island in the middle called Chorao Island. The total area of the Chorao Island is 423.75 ha and the mangrove cover of the island is about 250 ha. The major mangrove species of Chorao island are *Rhizophora apiculata, R. mucronata, S. alba, K. candel, A. marina, A. officinalis, B. gymnorhiza and B. parvifora.* The ground flora consists of *A. ilicifolius,* mixed with pneumatophores as well as seedlings of other mangroves, *Excoecaria agallocha* of about 1.2 meters height formed the borderline of the mangrove zone, especially along the bunds.

Salinity: Salinity is the most conspicuous feature of the estuary so much so that it is a factor used to define the limits and characteristics of an estuary. When salinity patterns are studied, all through the year, it is seen that Mandovi - Zuari estuaries grade from well mixed type during pre-monsoon to partially mixed type during post monsoon with an intermediate stratified type during monsoon (Fig.6).

Suspended Sediment: The studies carried out by earlier workers from National Institute of Oceanography, before 1980, presents widely varying conditions depending upon the period of observations and their locations. However, the suspended sediment load was found to increase with the depth and with the current speed at all stations irrespective of seasons. The studies showed that during monsoon season, maximum values of suspended sediment were obtained at all depths at various stations. The study in the Zuari estuary showed that the maximum suspended sediment load was encountered towards upstream and minimum at the mouth.

Mine dumps- a source of additional material: In Goa, valuable ore bodies are located in thick forest areas or adjacent to them. Deforestation, therefore, is inevitable as 70% of the mining in Goa is carried out in forest areas. Mining has been responsible for limiting thick forest to the eastern portion of the state, i.e. restrict it to only the Western Ghats. The cutting of forests resulted in uncontrolled erosion. Damage to forestland is particularly seen in Bicholim-Sirigao area, Pissurlem-Sonshi area, Surla-Pale area and Odamol-Tathodi area. Sliding and slumping of land, due to large-scale excavations in surface mining is the basic cause of land degradation. Land degradation due to mining can be categorised into three (a) Land excavated to win the ore (b) Land used for dumping and (c) Land degraded due to erosion and other processes. Each year 30 to 45 million tonnes of rejects are generated and stacked in large dumps in the state. With this rate, in the remaining 30 years, mining will continue to add over 4000 million tonnes of mine dump. The result is huge quantity of loose material production and available for easy transport from the catchment area.

Rainfall as a factor for transport of Mine-Waste: The hydrological regime, in Goa is controlled by rainfall especially in the upper reaches of rivers. Though the major rainfall is restricted to 4 months of southwest monsoon, as it provides over the rainfall controls 90% of the total rainfall, the run off and the river flow. The data collected from various rainfall-recording stations of Goa through India Meteorological Department helped to understand how the rainfall/run off plays a role in transporting material from catchment area to the estuarine system.

The rainfall data collected from 1974 to 1998 for the southwest monsoon months namely June, July, August and September from the stations, which are situated in the catchment area of Mandovi and Zuari rivers are grouped as follows.

Group-I represents rainfall data of two stations namely Valpoi and Sanguem, which are located on the eastern part of Goa region. The South-West monsoon rainfall year wise totals from 1974 to 1998 for Valpoi ranges from 2927 mms (year 1986) to 4967 mms (year 1988). The values plotted (Fig.7) shows wavy in nature with ups and down especially between 1974 to 1991. The plot also reveals on an average there is slight reduction in rainfall from the beginning to end between the years selected at those locations. The other location namely Sanguem also shows similar characteristic as that of Valpoi. At Sanguem the rainfall data vary from 2692 mms (year 1993) to 4991 mms (year 1974).

The middle region of Mandovi and Zuari catchment area in the north-south direction is known for extensive mining activity. To represent this zone, Rainfall data collected from two stations namely Ponda and Quepem are presented in Group-II. The data for Ponda station when total rainfall of monsoon months is considered, it varies between 1837 mm (year 1986) and 4476 mm (year 1975). For Quepem it ranges between 2543 mm (year 1979) and 5100 mm (year 1975), the data plotted (Fig.8) represents wavy in nature and also shows slight reduction in rainfall activity from 1974 to 1998 when compared.

To represent the western region of Mandovi and Zuari catchment area, the rainfall data were collected from three stations namely Mapusa, Panjim and Marmugoa, which are represented in Group-III. The rainfall values are ranging between 1827 mm (year 1974) and 3896 mm (year 1983) for Mapusa, between 1621 mms (year 1986) and 3447 mms (year 1983) for Panjim station and 1522 mm (year 1986) and 3328 mm (year 1983) for Marmugao. The available data plotted (Fig.9) shows the rainfall curve, wavy in nature with the slight increase in rainfall especially from 1986 to 1988.

It is clear from the rainfall data that eastern region receives relatively higher rainfall and this rain water flows through middle and western part of the catchment area before the rivers merge into Arabian Sea. Similarly the rainfall received by the middle portion of the catchment area, which is located between eastern and western, also flows through Western to join Arabian Sea. The rainfall received by the eastern and middle region during the four monsoon months acts as a strong agent in transporting loose material, which was dumped on the valley sides by the mining industries.

Impact at Source: Among all the activities, mining appears to be one of the most degrading actions of man on the Earth (Nayak – 1998), whose impact on the environment has created a number of mind boggling environmental problem (Ganihar, 1990). The process of extraction of mineral resources and its use in various ways generate wide range of environmental changes. Sometimes having far reaching consequences (Veeresh, 1989) as demands for minerals grow, the area of mining would expand at faster rate, threatening increasingly larger areas of landscape with scarification, debris dumps, soil degradations, deforestation and distress to the population affected.

Soil, rich in mine material is found to be rich in iron, manganese and aluminium and deficient in micro nutrients - Nitrogen, Potassium and Phosphorous and also in calcium, magnesium and organic matters. It is stated that clay hinders the growth of the plants especially the penetration of the roots into the soil because of its compact nature. It is reported that chlorophyll content, sugar and protein content in plants also get decreased. Deforestation and blasting leads to the migration of animals. This eventually affects the biodiversity in the forests.

Iron ore belts in the mining regions are aquifers. In mines, where workings have gone below the water table, pumping out (150 million cubic m/year) of water from the mining pits, besides polluting the water streams, has resulted in the depression of the water table. Due to this, water levels in the wells located around are reduced and also water became turbid. As per Swaminathan (1982) as the mining activity extends deeper in search of ore, well water supply to the inhabitants is likely to be affected adversely.

The overburden in the mining area is generally removed by blasting. There are many reports of ground vibrations and damage to structures in the vicinity of mining area due to heavy blasting. Noise level above threshold has also been reported. Similarly air pollution is a serious concerned.

Damage to Agricultural land: In Goa, the mines are situated on hillocks and invariably the agricultural fields and villages are located at the foothills. Naturally the rainwater flows down the hills, which carries huge quantities of silt to the agricultural fields. Damage of agricultural land has mainly been related due to reject - pumping of muddy waters from the working pits including those where the mine workings gone below the water table and also slimes from the beneficiation plants. Mine reject being clayey in nature, it reduces porosity of soil and affects yield of agriculture. There are large numbers of reports regarding adverse effects of mining on yield of agricultural land. In addition, flash floods bring reject material and dump on agricultural fields. All these activities increases acidity and reduces porosity of soil, which reduces the fertility.

Impact on Water Bodies: Mining affects severely the hydrological regime through direct discharge of mine water to the stream and also due to erosion and wash off/run off from the mined out area and waste dumps (Chaudhary, 1994). In most of the mines in Goa, the ore is found below the water table and to extract this ore, the water is pumped out from the pits in turbid condition. In addition, colossal amount of ore rejects are dumped here and there around the mine pits, near lakes, rivers, agricultural fields and human habitations. Winds and rain erode these dumps and this is creating environmental disturbances. The run-off carries large quantity of fine material of the dumps from the catchment area to the river water bodies. Because of heavy showery precipitation, the erosion of such fine material is tremendous. This has lead to cause thick and quick growth of silting in the beds of streams and rivers. The flooding has become an annual in some places resulting the tributaries overflow.

The water is turned to acidic, charged with the dissolved chemical and with very high suspended solid particles. The rivers polluted due to mining activities in Goa are Bicholim, Harvalem, Madei and Khandepar. Bicholim river is polluted mainly due to direct run off of the nearby dumps and beneficiation plants. Harvalem River is polluted due to large pumping of mine-waters from Pissurlem, Sonshi, Deulem and Cundem mines. The extent of silting appears to be quite grave in some tributaries close to Pale mine. Rivers are also polluted fast due to slimes. The barge-traffic, loading platforms are major source of making river/estuary polluted.

The research work carried out (Nayak 1993, Bukhari 1994), on Mandovi and Zuari, 1989 onwards shows large increase in the values of suspended sediment. These studies based on monthly collection of data for over a period of one year, have reported the total suspended matter values between 2.22 mg/l and 60.49 mg/l in pre-monsoon, 10.54 mg/l and 166.03 mg/l in monsoon, 1.06 mg/l and 56.48 mg/l in post monsoon for Mandovi. Similarly, for Zuari 1.92 mg/l and 185.44 mg/l in per-monsoon, 5.14 mg/l and 219.53 mg/l in monsoon, 3.46 mg/l and 293.19 mg/l in post monsoon. The changes have been interpreted as mainly due to additional input of both suspended and bed load that they have linked to release of material from open cast mining activities. Further they have stated that during fair weather season, sea acts as a source and during monsoon hinterland for these estuaries. The studies have also revealed that the geomorphic set up of the estuary also plays an important role in defining the parameters/characteristics of the estuary. For example the waters of Zuari estuary are more saline than Mandovi. These studies have shown that the concentration of total suspended matter in bottom waters is always higher than that of surface waters in the estuarine region. They have also interpreted that factors like tide/tidal currents control the estuarine processes during fair weather season and land runoff during monsoon season. Monsoon rain as explained earlier, acts as a main agent in the process of transport of mine-waste to the Mandovi and Zuari estuaries. It seen that there is a direct relation between rainfall and total suspended matter in the estuary (Fig.10). Studies (Nayak, 1993) have shown that the tributaries those are pass through the mining zones contain very high concentration of total suspended matter and the estuarine waters hold extremely high concentration of suspended matters.

The chief factor variables that determine the processes in an estuary are fresh water influx / river discharge and tides, waves and meteorological and oceanographic forces. Most of these factors are defined by climate. However, processes are made more complex when any one parameter is predominant. Turbidity increases with higher concentration of total suspended matter and reduces the amount of light to planktonic life and therefore productivity decreases. The studies also showed the suspended matters and soluble iron had affected the quality and the quantity of phytoplankton in the water bodies. Mine tailings deposited in the estuarine zone suffocates the benthic fauna. Metals like Fe, Mn, Cr, Ni, Co, Zn, Pb which are carried by adsorption from mines on clays settles within the estuary due to high salinity. NIO studies have shown that various organisms like Mackeral, Indian Herring and Shad are known to bio-accumulate heavy metals. High turbidity also creates siltation problem with the water bodies. The extent of pollution of estuarine and river sediments were computed by using formula for index of geoaccumulation. of Muller(1979), These studies have proved that mid reaches of the estuaries and tributaries are affected by higher concentration of Fe, Mn, Cr and are moderately to strongly polluted by these elements(Bukhari,1994). Release of ammonia from beneficiation plants to the estuary has reported to create imbalance in nutrient budget and therefore affect productivity. Recent study (Nigam, et al., 1998) on Mandovi estuary showed decrease in species of Foraminifera both in number and the species which has been related to increase of suspended load when compared to 18 years old data. This proves that the large quantity of material transport from catchment area of these rivers/tributaries, due to human interference in the form of mining activity, to sea through the estuarine/ coastal regions, has affected the estuarine environment to a considerable extent.

It is clear from the earlier study that Mandovi and Zuari estuarine including Kumbarjua canal system have badly affected by mine-waste material discharged incessantly from mining industry. Ever increasing entry of such mining reject, which reduced the healthy and highly productive estuarine environment. Unless it is prevented, it will result in the extinction of large estuarine life in near future.

References:

Balakrishnan, Nair, N.; Abdul Aziz P. K.; Arunachalam, M.; Krishnakumar K.; and Dharmaraj, K. (1984); *Ecology of Indian estuaries, 10. Distribution of total nitrogen and total potassium in the sediments of ashtamudi estuary*, Mahasagar, Vol., 17, pp 33-39.

Borole, D. V.; Krishnaswami S.; Somayajulu, B.L.K. (1982); *Uranium isotopes in rivers, estuaries and adjacent coastal sediments of western India; their weathering, transport and oceanic budget*, Geochim. Cosmochim. Acta, V.46, pp 125-137.

Bukhari, S. S. (1994); *Studies on mineralogy and geochemistry of bed and suspended sediment of Mandovi river and its tributaries in Goa, West Coast of India, Ph.*D. thesis, Goa University, Goa, 240 p.

Chaudry, S.K.(1994); *Water pollution, environment aspect of mining areas,* bulletin No. 27, Indian Bureau of Mines, pp 37 - 40.

Ganihar, S.R.(1990); *Impact of mining on the faunal composition of Goa,* Ph.D. thesis submitted to Goa University(Unpublished), 264 p.

Gune, V.T. (1979); *Gazetter of the Union Territory, Goa, Daman and Diu,* District Gazetter part - I, Goa pp 1-1023.

Muller,G.(1979); *Rezichungen Zwischen Wasserkorper, Bodensediment und Organismen in Bodensee,* Naturwise, V.54, pp.454-466.

Nair, S. M,; Balachand, A. N.; and Nambisan, P.N.K. (1990); *Metal concentration in recently deposited sediments of Cochin backwaters,* Indian Sci. total environ., Vol.97-98, pp 507-524.

Nair, E.V. (1989); *Grain size characteristics and distribution pattern of marine sediments off Karwar coast, Karnataka State,* Geological Survey India Special Publication No. 24, pp 43-50.

Nayak, G.N. (1993); *Studies on sediment flux of rivers, estuaries and adjoining coastal waters of Goa, West coast of India,* Tech. Rep., Ministry of Environment, Govt. of India.

Nayak, G.N.(1994); *Impact of mining on Environment in Goa-Present status,* Tech. Rep. Ministry of Environment, Govt. of India.

Nayak, G.N. (1998*); Impact of mining on environment in Goa: a review,* Environmental Geochemistry V.1 pp 97 - 100.

Nayak, G. N. and Bukhari, S. S. (1993); *Spatial and Temporal distribution of total suspended matter and other associated parameters in the Zuari estuary, Goa, Jour.* Ind. Assoc. Sedimentologists Vol. 11 pp 55-69.

Nigam, R., Nayak, G.N. and Naik,S.(1998); *Foraminiferal distribution in Mandovi estuary sediments with special reference to mining pollution,* XVI Ind. Coll. On Micropal. & Strat.(Abstract), 101 pp.

Oertal, G.(1958); *A Geologia do distrito de Goa Geological Services of Portugal,* Lisbon.

Reddy, Y.S.(1985); *Basic concepts to improve operational effeciency in Goan Iron mines.* In Earth Resources for Goa's Development pp 270 - 272.

Salgaonkar, S.V.(1991); *Goan iron ore Industry, historical back ground and present status* - Goa Mineral Ore Exporter Association pp1-32.

Swaminathan, M.S.(1982); *Report of the task force on Eco-Development plan for Goa,* Government of India, New Delhi, pp136.

Veeresh, A.V.(1989); *Responsible of plant species to the mining rejects,* Ph.D. thesis submitted to Goa University(Unpublished), 188 p.

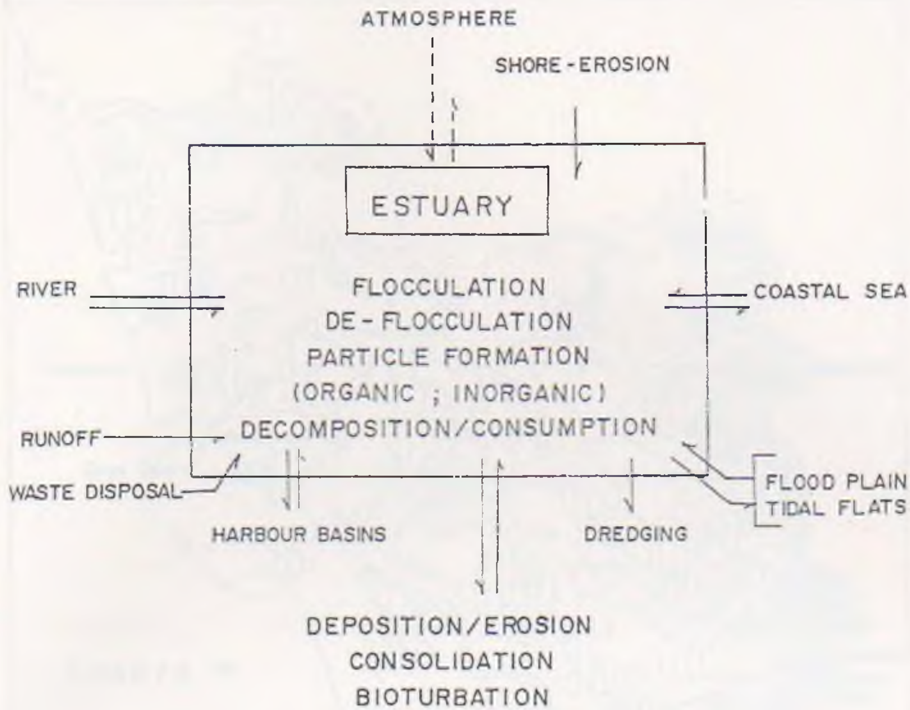


FIG. I GENERAL SCHEME OF SUPPLY AND REMOVAL OF SEDIMENTS IN ESTUARIES (After Eisma and Burg, 1988)

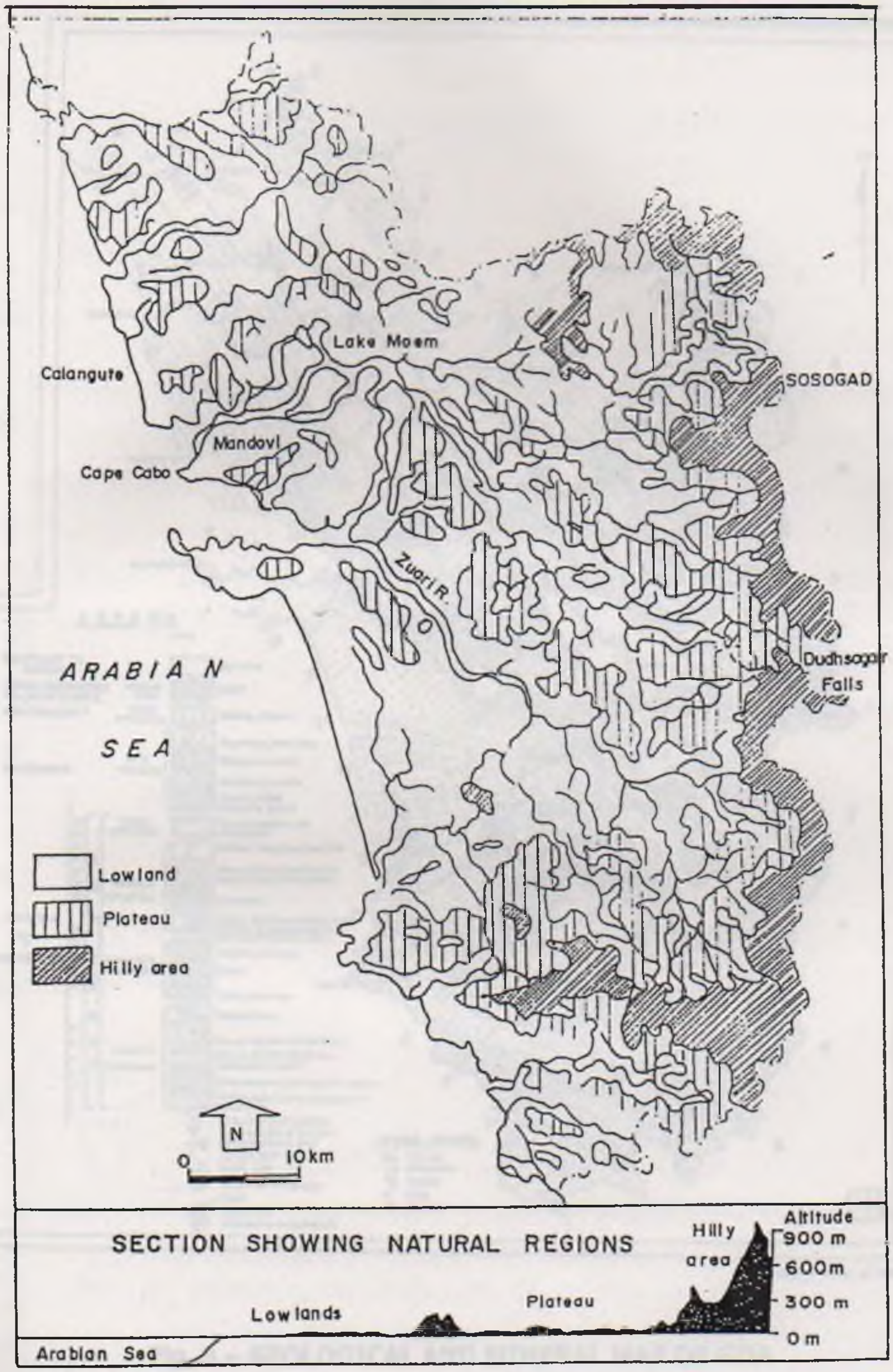
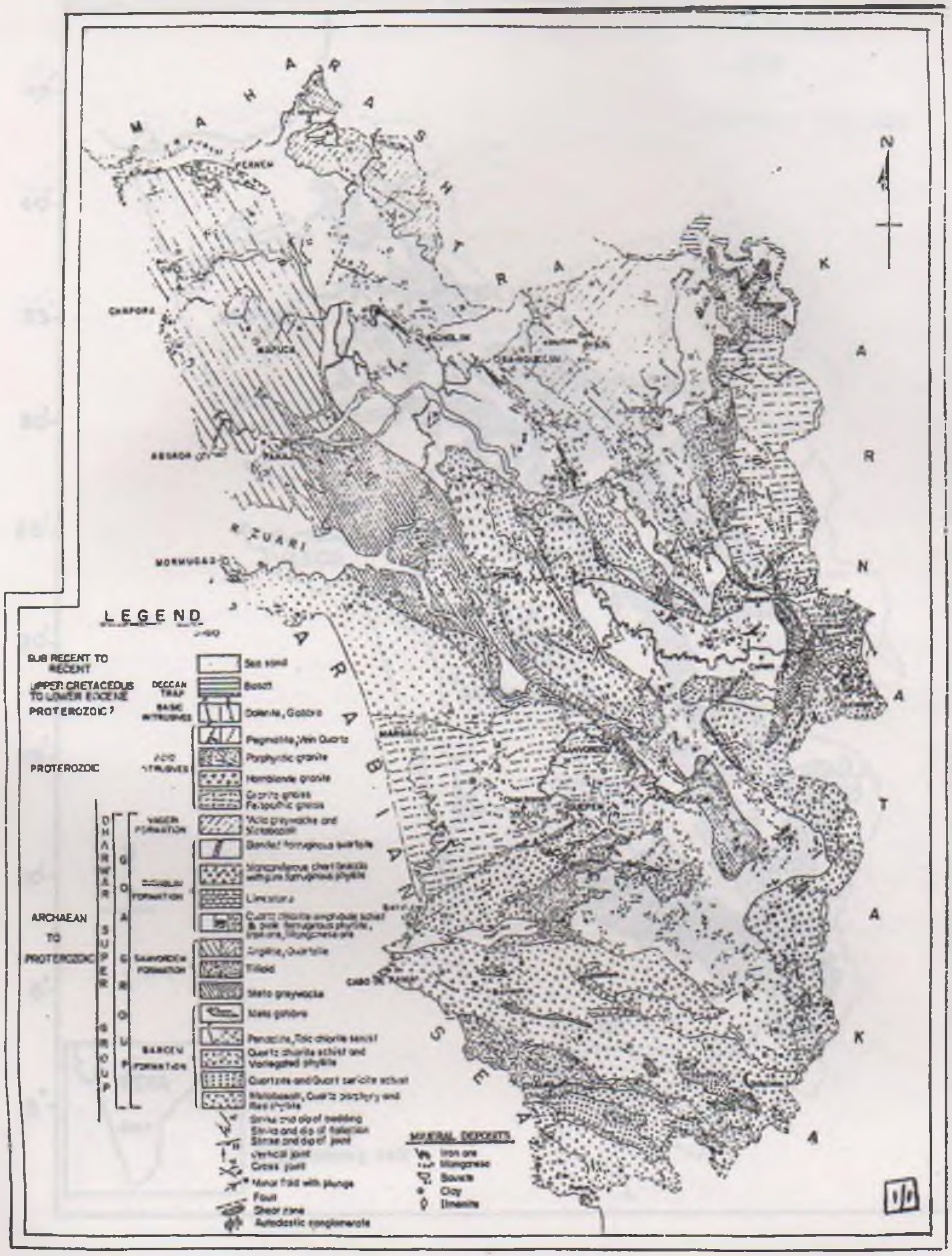


FIG. 2 PHYSIOGRAPHIC DIVISIONS OF GOA STATE



Geological Survey of India.

Fig. 3 – GEOLOGICAL AND MINERAL MAP OF GOA

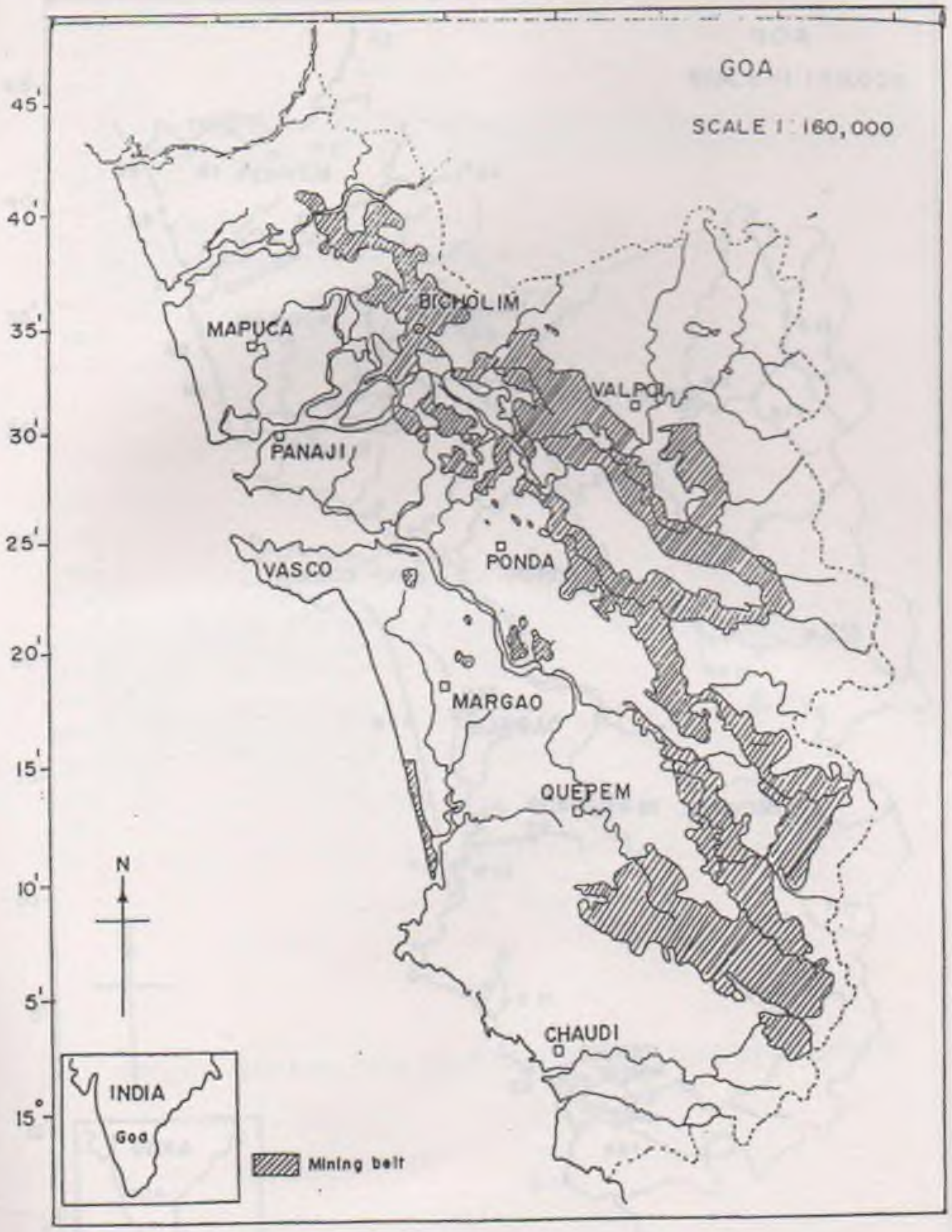


FIG. 4 GENERAL DISTRIBUTION OF MINES IN GOA

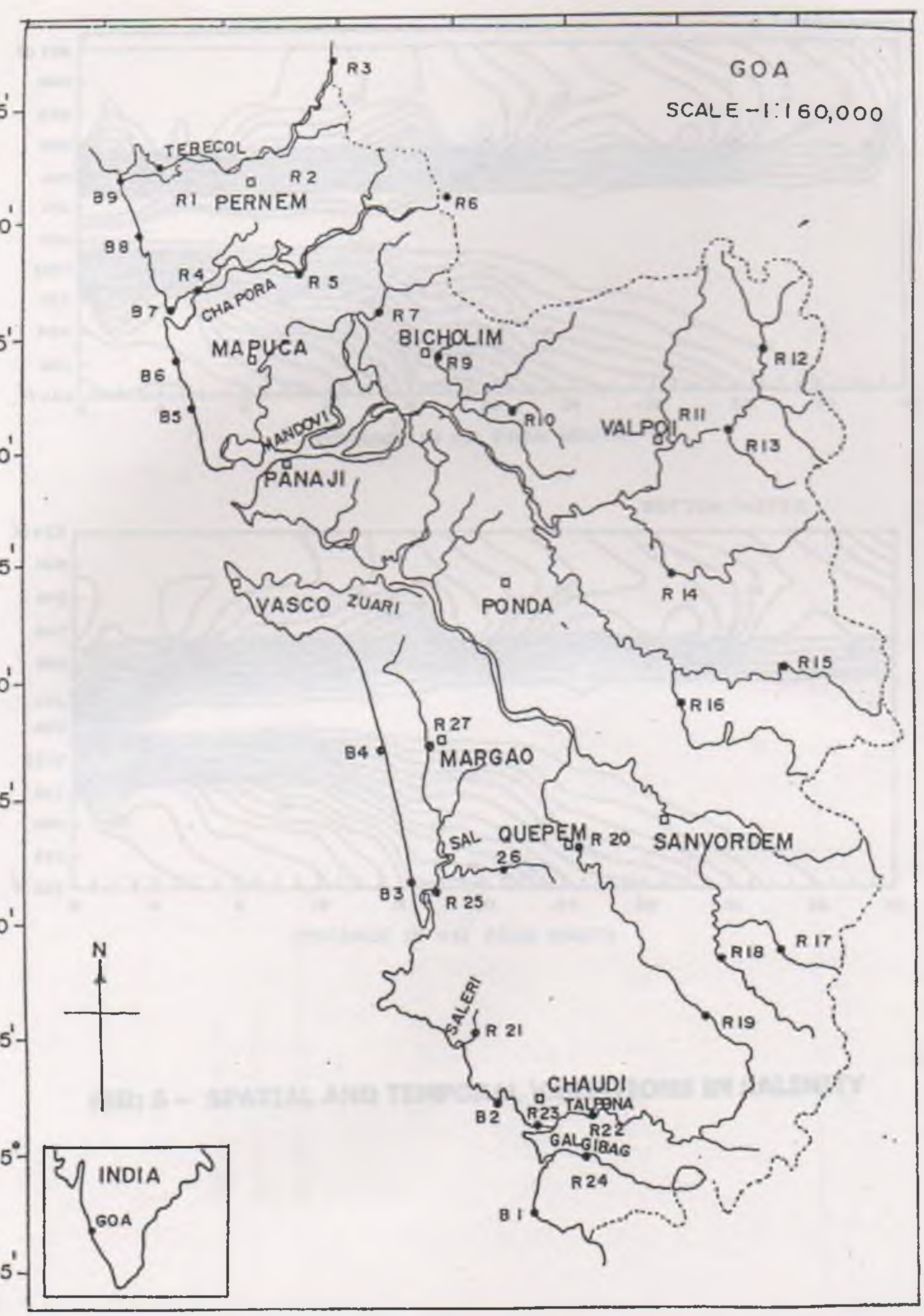


FIG. 5 RIVERS OF GOA

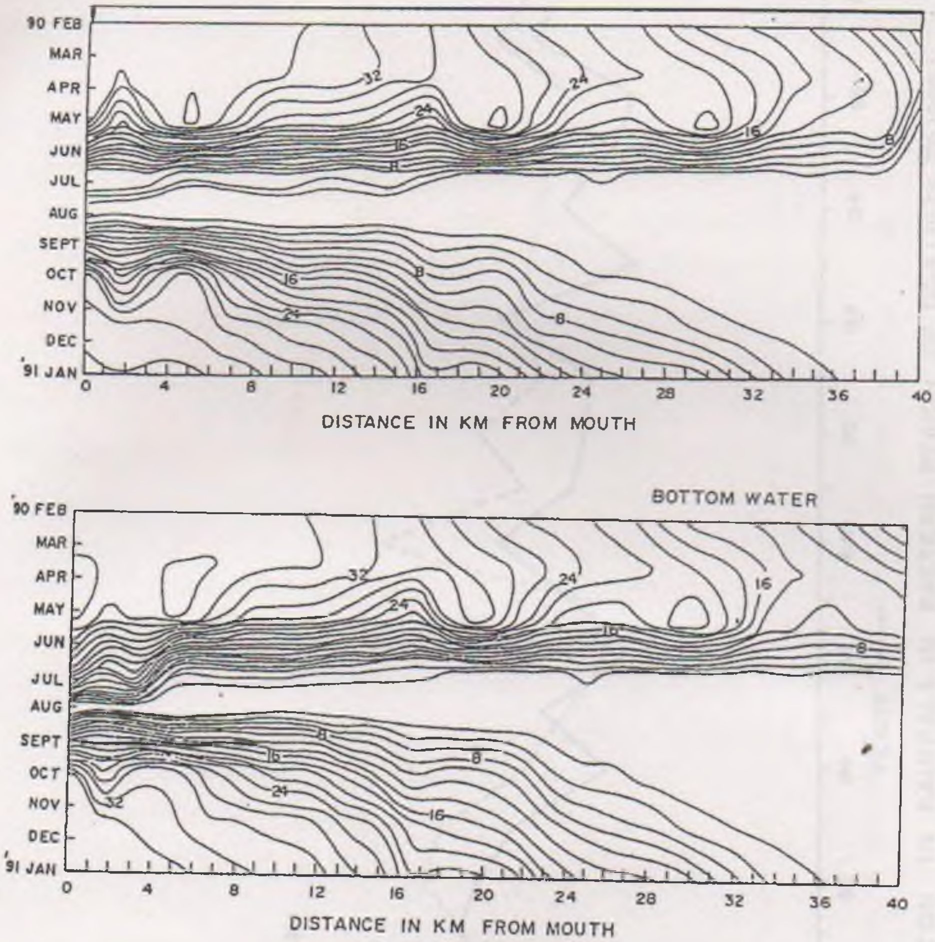


FIG: 6 – SPATIAL AND TEMPORAL VARIATIONS IN SALINITY

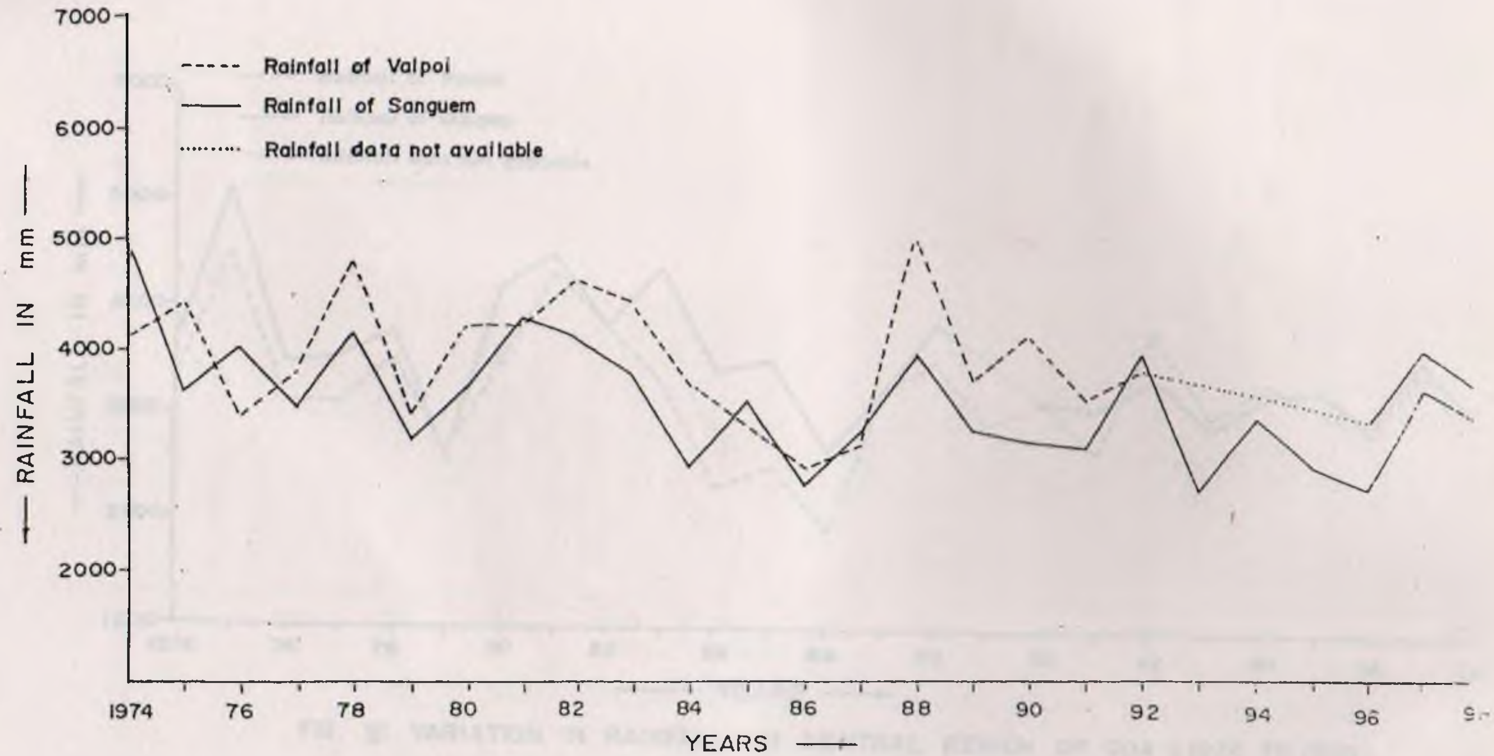


FIG. 7. VARIATION IN RAINFALL IN EASTERN REGION OF GOA (1974 TO 1998)

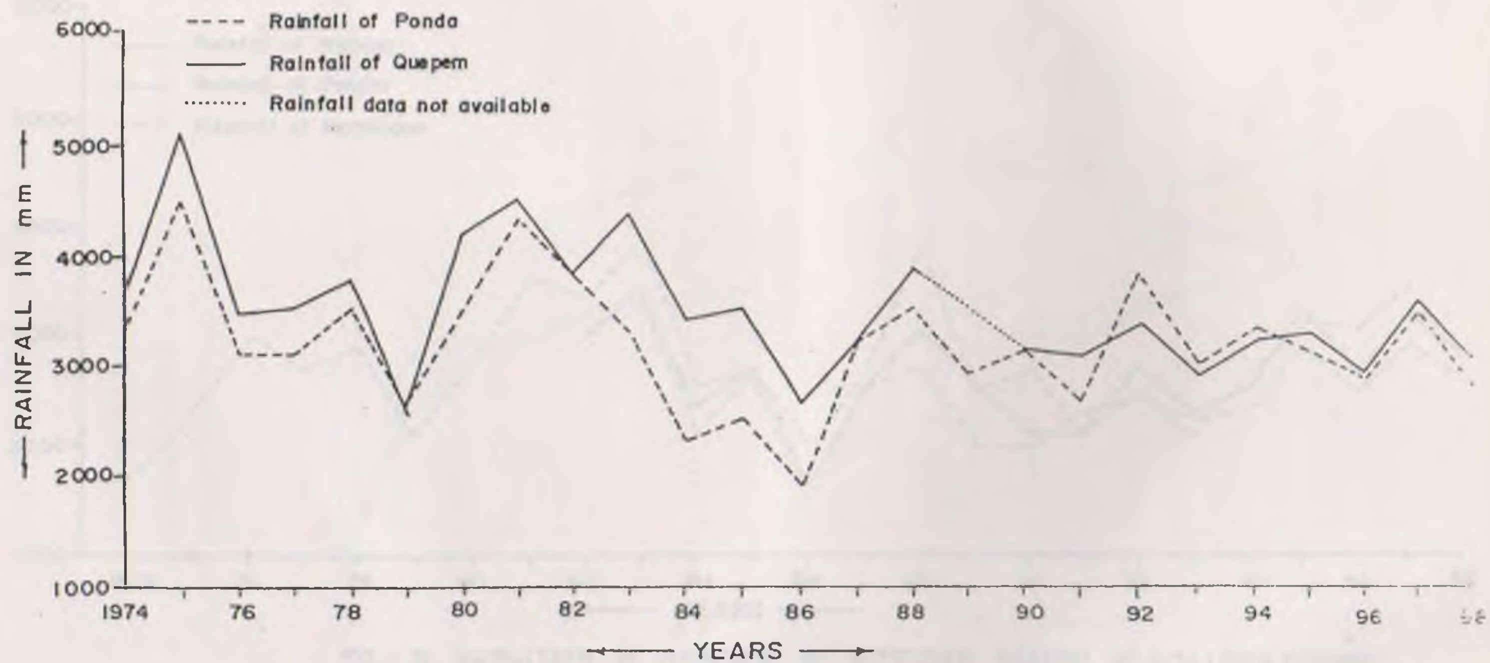


FIG. 8. VARIATION IN RAINFALL IN CENTRAL REGION OF GOA (1974 TO 1998)

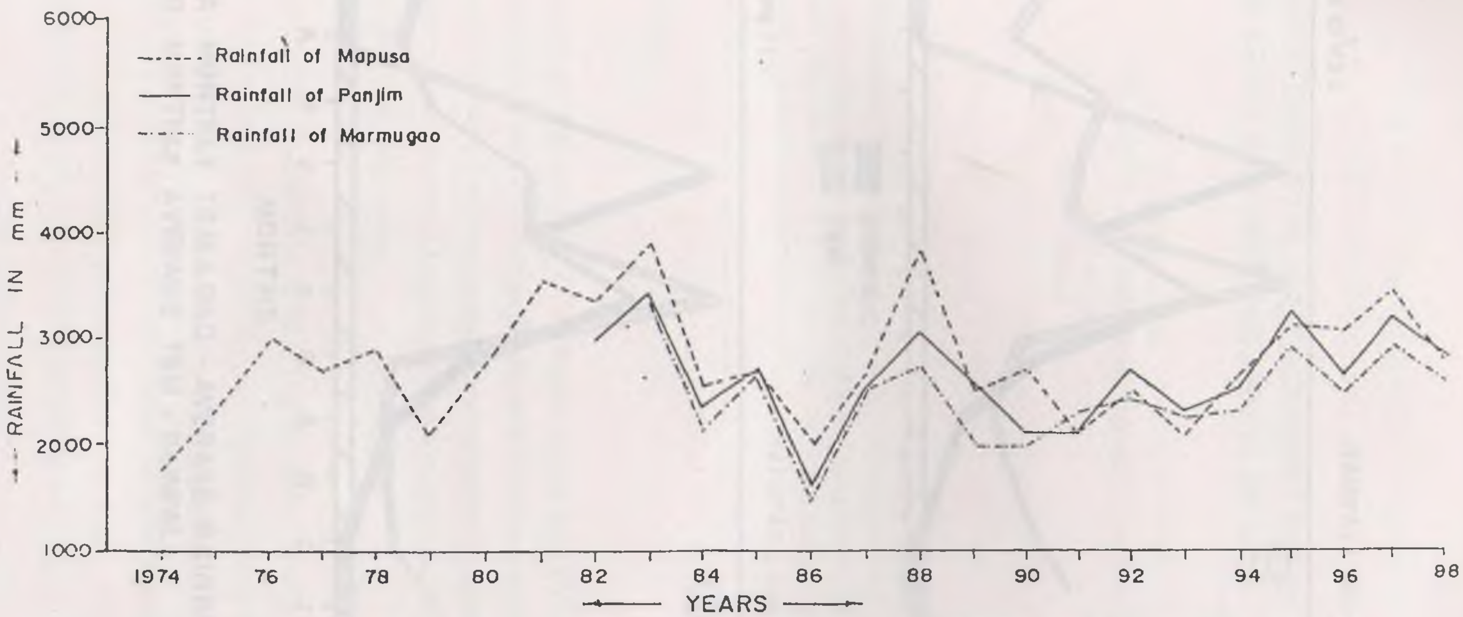


FIG. 9 VARIATION IN RAINFALL IN WESTERN REGION OF GOA (1974 TO 1998)

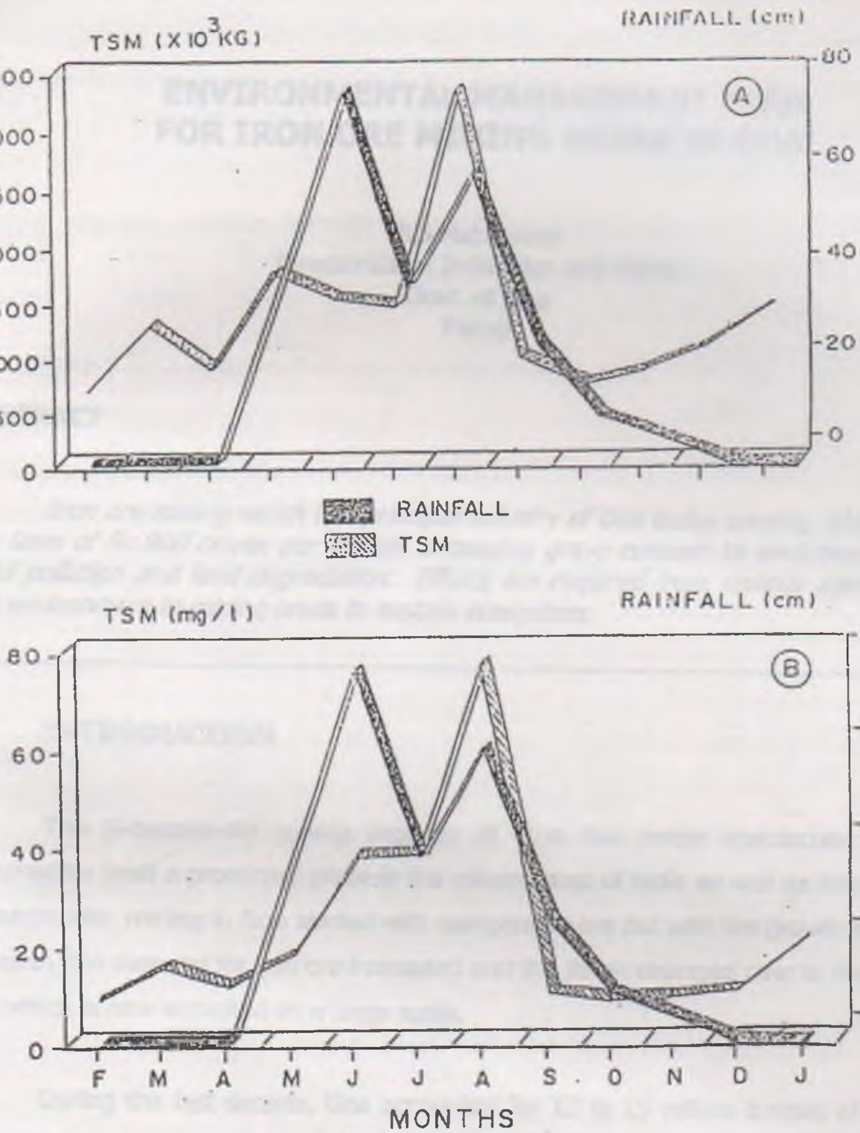


FIG. 10 A MONTHLY TSM LOAD - AVERAGE RAINFALL
B. MONTHLY AVERAGE TSM - RAINFALL